Impact of CP phases on SUSY particle production and decays

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ABSTRACT: We report on the results of a phenomenological study of top squarks ($\tilde{t}_{1,2}$) and bottom squarks ($\tilde{b}_{1,2}$) in the Minimal Supersymmetric Standard Model (MSSM) with complex parameters A_t, A_b, μ and M_1. In particular we focus on the CP phase dependence of the branching ratios of $\tilde{t}_{1,2}$ and $\tilde{b}_{1,2}$ decays. We find that the effect of the phases on the $\tilde{t}_{1,2}$ and $\tilde{b}_{1,2}$ decays can be quite significant in a large region of the MSSM parameter space. We also study a CP asymmetry in sfermion decays.

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1. Introduction

Supersymmetry (SUSY) is one of the best studied extensions [1] of the Standard Model (SM). SUSY gives us also the benefit of introducing potential new sources of CP violation [2]. As the small amount of CP violation in the SM is not sufficient to explain the baryon asymmetry of the universe, it is necessary to study all implications of the complex SUSY parameters. The search for SUSY will be one of the main goals of all future colliders. An e^+e^- linear collider will be an ideal machine for the determination of the underlying SUSY parameters [3].

In this talk we present the results of our studies [4, 5, 6] of the effects of complex SUSY parameters on the phenomenology of the scalar top quark and scalar bottom quark system. Analysing the properties of 3rd generation sfermions is particularly interesting, because of the effects of the large Yukawa couplings. The lighter sfermion mass eigenstates may be among the light SUSY particles and they could be investigated at e^+e^- linear colliders [7, 8]. Previous analyses of the decays of the 3rd generation sfermions $\tilde{t}_{1,2}$, $\tilde{b}_{1,2}$, $\tilde{\tau}_{1,2}$ and $\tilde{\nu}_\tau$ in the Minimal Supersymmetric Standard Model (MSSM) with real parameters have been performed in Refs. [9]–[11].

In the MSSM the SUSY parameters A_f, μ and M_i ($i = 1, 2, 3$) are in general complex, where A_f is the trilinear scalar coupling parameter of the sfermion $\tilde{f}_i$, μ is the Higgs-higgsino mass parameter and M_1, M_2 and M_3 are the U(1), SU(2) and SU(3) gaugino mass parameters, respectively. We will first study the phase dependence of the decay branching ratios of the top squarks and bottom squarks, which are CP-even observables. As we will show, the phase dependence of these decay branching is indeed suitable to obtain informations about the SUSY CP phases. The situation is quite similar to that of the third generation slepton system, where the decay branching ratios of the staus $\tilde{\tau}_{1,2}$ and τ-sneutrino $\tilde{\nu}_\tau$ can be used to get information on the phases of the stau and gaugino-higgsino sectors [12]. In our study we will use the MSSM as a general framework and assume that the parameters A_t, A_b, μ and M_1 have the phases φ_{A_t}, φ_{A_b}, φ_μ and $\varphi_{\mathrm{U}(1)}$, respectively (taking $M_{2,3}$ real). We take into account explicit CP violation in the Higgs sector [13, 14, 15]. Furthermore, we also take into account the constraints on the SUSY parameters which follow from the experimental data on the rare decay $b \to s\gamma$ [16].

We will also consider a CP-odd observable in sfermion decays, which provides a more direct signal for the presence of CP phases. This observable is a CP-sensitive asymmetry which follows from triple product correlations [6, 17].

2. Decay Branching Ratios of Top Squarks and Bottom Squarks

Considering first top squark and bottom squark production, the reaction $e^+e^- \to \tilde{q}_i \bar{\tilde{q}}_j$, $\tilde{q}_i = \tilde{t}_i, \tilde{b}_i$, proceeds via γ and Z exchange in the s-channel. The tree-level cross sections [8] of these reactions do not explicitly depend on the phases φ_μ and φ_{A_q}, because the $Z\tilde{q}_i\tilde{q}_i$ couplings are real and in $e^+e^- \to \tilde{q}_1 \bar{\tilde{q}}_2$ only Z exchange contributes. The cross sections depend only on the mass eigenvalues $m_{\tilde{q}_{1,2}}$ and on the mixing angles $\cos^2\theta_{\tilde{q}}$. Therefore,

they depend only implicitly on the phases via the $\cos(\varphi_\mu + \varphi_{A_q})$ dependence of $m_{\tilde{q}_{1,2}}$ and $\theta_{\tilde{q}}$.

In the following we will present numerical results for the phase dependences of the $\tilde{t}_i$ and $\tilde{b}_i$ partial decay widths and branching ratios. We will treat the fermionic decays

$$\tilde{q}_i \to q' + \tilde{\chi}_k^{\pm}, i = 1, 2, k = 1, 2 \tag{2.1}$$

and

$$\tilde{q}_i \to q + \tilde{\chi}_k^0, i = 1, 2, k = 1, .., 4 \tag{2.2}$$

and the bosonic decays

$$\tilde{q}_i \to W^{\pm} + \tilde{q}_j', i = 1, 2, j = 1, 2, j \leq i, \tag{2.3}$$

$$\tilde{q}_i \to H^{\pm} + \tilde{q}_j', i = 1, 2, j = 1, 2, j \leq i, \tag{2.4}$$

$$\tilde{q}_2 \to Z + \tilde{q}_1, \tag{2.5}$$

and

$$\tilde{q}_2 \to H_i + \tilde{q}_1, i = 1, 2, 3. \tag{2.6}$$

These partial decay widths depend on the SUSY parameters of the squark system $M_{\tilde{Q}}$, $M_{\tilde{U}}$, $M_{\tilde{D}}$, $\tan\beta$, $|\mu|$, φ_μ, $|A_t|$, φ_{A_t}, $|A_b|$, φ_{A_b}, which determine the mass eigenvalues and mixing angles of the top and bottom squarks. In addition, in the chargino sector the $SU(2)$ gaugino mass parameter M_2 enters. The mass eigenvalues and mixing of the neutralino depend also on the $U(1)$ gaugino mass parameter M_1 with phase $\varphi_{U(1)}$ which, therefore, influences the partial decay widths of the top and bottom squarks into neutralinos. The main parameter of the Higgs sector is the charged Higgs boson mass $m_{H^\pm}$, in addition to the parameters already introduced.

We calculate the partial decay widths in Born approximation. In some cases the one-loop SUSY QCD corrections are important. The analyses of [10, 11, 18] suggest that a significant part of the one-loop SUSY QCD corrections to the partial widths of $\tilde{t}_i$ and $\tilde{b}_i$ decays (where the bottom Yukawa coupling is involved) can be incorporated by using an appropriately corrected bottom quark mass. In this spirit we calculate the tree-level widths of the $\tilde{t}_i$ and $\tilde{b}_i$ decays by using on-shell masses for the kinematic terms (such as phase space factors) and by taking running t and b quark masses for the Yukawa couplings. For definiteness we take $m_t^{\text{run}}(m_Z) = 150$ GeV, $m_t^{\text{on-shell}} = 175$ GeV, $m_b^{\text{run}}(m_Z) = 3$ GeV and $m_b^{\text{on-shell}} = 5$ GeV. This approach leads to an "improved" Born approximation which takes into account an essential part of the one-loop SUSY QCD corrections to the $\tilde{t}_i$ and $\tilde{b}_i$ partial decay widths and predicts their phase dependences more accurately than the "naive" tree-level calculation. In the calculation of the CP violating effects in the neutral Higgs sector we take the program FeynHiggs-2.0.2 of [15].

In the numerical analysis we impose as theoretical constraint the approximate necessary condition for the tree-level vacuum stability [19]. Furthermore, as experimental constraints we take into account the mass bounds from LEP [20] and $\Delta\rho(\tilde{t} - \tilde{b}) < 0.0012$ [21], as well as $2.0 \times 10^{-4} < B(b \to s\gamma) < 4.5 \times 10^{-4}$ [16] assuming the Kobayashi-Maskawa mixing
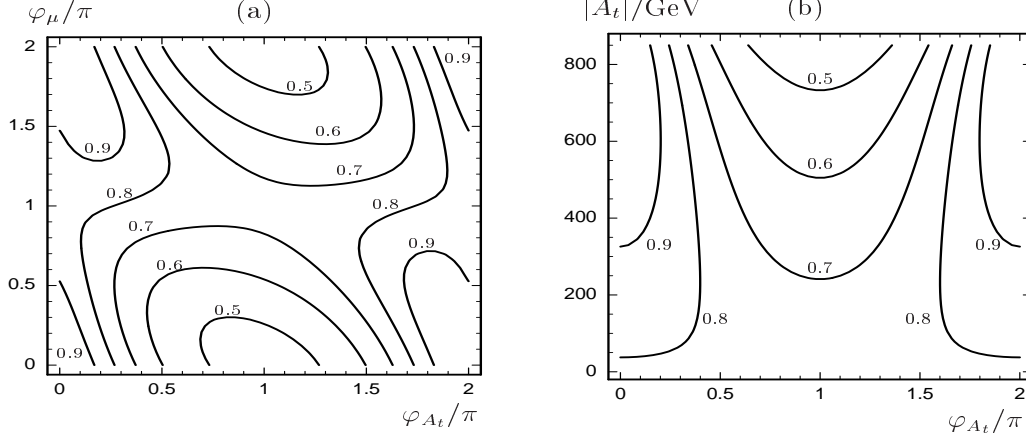
Figure 1: Contours of $B(\tilde{t}_1 \to \tilde{\chi}_1^0 t)$ for $\tan\beta = 6$, $M_2 = 300$ GeV, $|\mu| = 500$ GeV, $\varphi_{U(1)} = \varphi_{A_b} = 0$, $m_{\tilde{t}_1} = 350$ GeV, $m_{\tilde{t}_2} = 700$ GeV, $m_{\tilde{b}_1} = 170$ GeV, $m_{H^\pm} = 600$ GeV, with (a) $|A_t| = |A_b| = 800$ GeV and (b) $\varphi_\mu = 0$, $|A_b| = |A_t|$, assuming $M_{\tilde{Q}} > M_{\tilde{U}}$.

also for the squark sector. For the calculation of the $b \to s\gamma$ width we use the formula of [22] including the $O(\alpha_s)$ corrections as given in [23]. We also take $|M_1| = 5/3 \tan^2\theta_W M_2$.

As a first example we show in Fig. 1 (a) the contour plot for $B(\tilde{t}_1 \to \tilde{\chi}_1^0 t)$ as a function of φ_{A_t} and φ_μ for $(m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{b}_1}) = (350, 700, 170)$ GeV, $\tan\beta = 6$, $M_2 = 300$ GeV, $|\mu| = 500$ GeV, $|A_t| = |A_b| = 800$ GeV, $\varphi_{U(1)} = \varphi_{A_b} = 0$ and $m_{H^\pm} = 600$ GeV, assuming $M_{\tilde{Q}} > M_{\tilde{U}}$. For the parameters chosen the φ_{A_t} dependence is stronger than the φ_μ dependence. The reason is that these phase dependences are caused mainly by the $\tilde{t}_L$ -$\tilde{t}_R$ mixing term, where the φ_μ dependence is suppressed by $\cot\beta$. The φ_μ dependence is somewhat more pronounced for $\varphi_{A_t} \approx \pi$ than for $\varphi_{A_t} \approx 0, 2\pi$. In Fig. 1 (b) we show the contour plot of $B(\tilde{t}_1 \to \tilde{\chi}_1^0 t)$ as a function of φ_{A_t} and $|A_t|$ for $\varphi_\mu = 0$ and $|A_t| = |A_b|$. Clearly, the φ_{A_t} dependence is stronger for larger values of $|A_t|$.

For the heavier top squark $\tilde{t}_2$ more decay channels are open. In Fig. 2 (a) we show the branching ratios for $\tilde{t}_2 \to \tilde{\chi}_{1,2}^+ b$ and $\tilde{t}_2 \to \tilde{\chi}_{2,3,4}^0 t$ as a function of φ_{A_t} for $(m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{b}_1}) = (350, 800, 170)$ GeV, $\tan\beta = 6$, $M_2 = 300$ GeV, $|\mu| = 500$ GeV, $|A_b| = |A_t| = 500$ GeV, $\varphi_\mu = \varphi_{U(1)} = \varphi_{A_b} = 0$, $m_{\tilde{t}_1} = 350$ GeV, $m_{\tilde{t}_2} = 800$ GeV, $m_{\tilde{b}_1} = 170$ GeV and $m_{H^\pm} = 350$ GeV, assuming $M_{\tilde{Q}} > M_{\tilde{U}}$. The φ_{A_t} dependence of $B(\tilde{t}_2 \to \tilde{\chi}_{1,2}^+ b)$ is due to a direct phase effect, which explains that the shape of $B(\tilde{t}_2 \to \tilde{\chi}_{1,2}^+ b)$ is like $(1 \pm \cos\varphi_{A_t})$. Also the phase dependence of the branching ratios into neutralinos is mainly due to a direct phase effect. $B(\tilde{t}_2 \to \tilde{\chi}_2^0 t)$ has a very weak phase dependence like $(10 + \cos\varphi_{A_t})$. In $\Gamma(\tilde{t}_2 \to \tilde{\chi}_3^0 t)$ the mixing phase enters, resulting in a shape like $(1 + \cos\varphi_{A_t})$ for the branching ratio. Similarly, $B(\tilde{t}_2 \to \tilde{\chi}_4^0 t)$ behaves like $(1 - \cos\varphi_{A_t})$.

In Fig. 2 (b) we show the branching ratios for the bosonic decays $\tilde{t}_2 \to Z\tilde{t}_1$ and $\tilde{t}_2 \to H_i\tilde{t}_1$ $(i = 1, 2, 3)$ for the same parameter values as above. The shape of $B(\tilde{t}_2 \to Z\tilde{t}_1)$

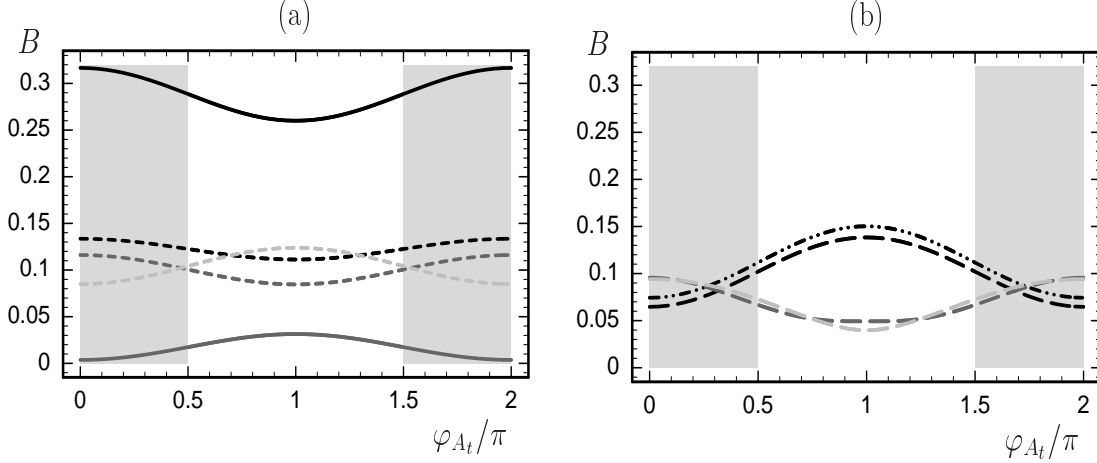**Figure 2:** φ_{A_t} dependence of branching ratios of the decays (a) $\tilde{t}_2 \to \tilde{\chi}^+_{1/2}b$ (solid, black/gray), $\tilde{t}_2 \to \tilde{\chi}^0_{2/3/4}t$ (dashed, black/gray/light gray) and (b) $\tilde{t}_2 \to Z\tilde{t}_1$ (dashdotdotted), $\tilde{t}_2 \to H_{1/2/3}\tilde{t}_1$ (long dashed, black/gray/light gray) for $\tan\beta = 6$, $M_2 = 300$ GeV, $|\mu| = 500$ GeV, $|A_b| = |A_t| = 500$ GeV, $\varphi_\mu = \varphi_{\mathrm{U}(1)} = \varphi_{A_b} = 0$, $m_{\tilde{t}_1} = 350$ GeV, $m_{\tilde{t}_2} = 800$ GeV, $m_{\tilde{b}_1} = 170$ GeV and $m_{H^\pm} = 350$ GeV, assuming $M_{\tilde{Q}} > M_{\tilde{U}}$. Only the decay modes with $B \gtrsim 1\%$ are shown. The shaded areas mark the region excluded by the experimental limit $B(b \to s\gamma) < 4.5 \times 10^{-4}$.

is like $(1 - \cos\varphi_{A_t})$, which is caused by the $\theta_{\tilde{t}}$ dependence of the corresponding coupling. Quite generally, the phase dependence of $\Gamma(\tilde{t}_2 \to H_k\tilde{t}_1)$ is the result of a complicated interplay among the phase dependences of the neutral Higgs boson masses, the top squark mixing matrix elements, the neutral Higgs mixing matrix elements and the direct top squark-Higgs couplings. In the present example the φ_{A_t} dependence of the partial widths $\Gamma(\tilde{t}_2 \to H_{1,2,3}\tilde{t}_1)$ is mainly due to the φ_{A_t} dependence of the top squark mixing matrix and the squark-Higgs couplings, whereas the φ_{A_t} dependence of the neutral Higgs mixing matrix is less pronounced in this case.

Coming now to the discussion of the decays of the bottom squarks $\tilde{b}_{1,2}$, we show in Fig. 3 the partial decay widths and the branching ratios of $\tilde{b}_1 \to \tilde{\chi}^0_{1,2}b$, $H^-\tilde{t}_1$, $W^-\tilde{t}_1$ as a function of φ_{A_b} for $m_{\tilde{b}_1} = 350$ GeV, $m_{\tilde{b}_2} = 700$ GeV, $m_{\tilde{t}_1} = 170$ GeV, $\tan\beta = 30$, $m_{H^\pm} = 150$ GeV, $M_2 = 200$ GeV, $|\mu| = 300$ GeV, $|A_b| = |A_t| = 600$ GeV, $\varphi_\mu = \pi$ and $\varphi_{A_t} = \varphi_{\mathrm{U}(1)} = 0$, assuming $M_{\tilde{Q}} > M_{\tilde{D}}$. In the region $0.5\pi < \varphi_{A_b} < 1.5\pi$ the decay $\tilde{b}_1 \to H^-\tilde{t}_1$ dominates. The φ_{A_b} dependence of $\Gamma(\tilde{b}_1 \to H^-\tilde{t}_1)$ is due to the behaviour of the squark-Higgs coupling. The partial decay widths $\Gamma(\tilde{b}_1 \to \tilde{\chi}^0_{1,2}b)$ are almost φ_{A_b} independent because the φ_{A_b} dependence of the bottom squark mixing matrix nearly vanishes for $\tan\beta = 30$. Hence the φ_{A_b} dependence of the branching ratios $B(\tilde{b}_1 \to \tilde{\chi}^0_{1,2}b)$ is caused by that of the total decay width. $\Gamma(\tilde{b}_1 \to W^-\tilde{t}_1)$ is suppressed because $\tilde{b}_1 \sim \tilde{b}_R$ and $\tilde{t}_1 \sim \tilde{t}_R$ in this scenario.

We have also estimated what accuracy can be expected in the determination of the underlying MSSM parameters by a global fit of the observables (masses, branching ratios
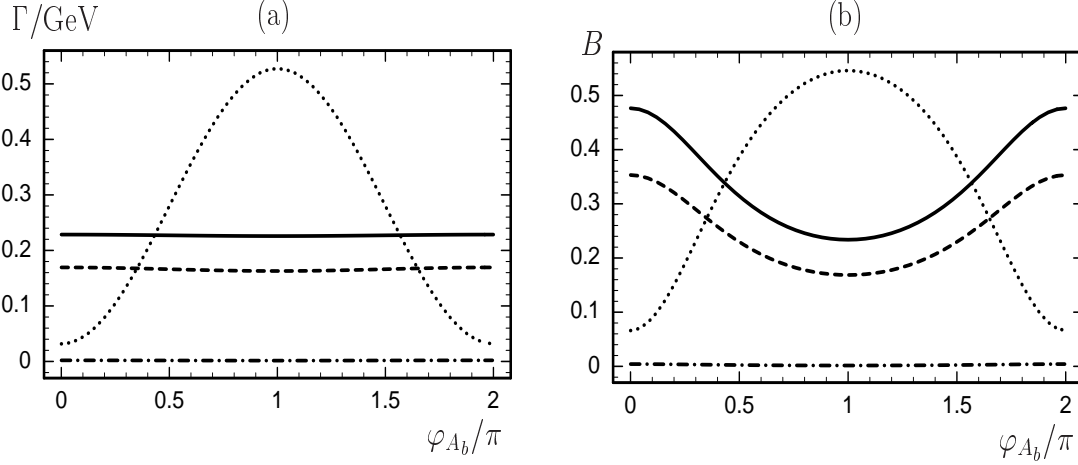
Figure 3: φ_{A_b} dependences of (a) partial widths and (b) branching ratios of the decays $\tilde{b}_1 \to \tilde{\chi}_1^0 b$ (solid), $\tilde{b}_1 \to \tilde{\chi}_2^0 b$ (dashed), $\tilde{b}_1 \to H^- \tilde{t}_1$ (dotted) and $\tilde{b}_1 \to W^- \tilde{t}_1$ (dashdotted) for $\tan\beta = 30$, $M_2 = 200$ GeV, $|\mu| = 300$ GeV, $|A_b| = |A_t| = 600$ GeV, $\varphi_\mu = \pi$, $\varphi_{A_t} = \varphi_{U(1)} = 0$, $m_{\tilde{b}_1} = 350$ GeV, $m_{\tilde{b}_2} = 700$ GeV, $m_{\tilde{t}_1} = 170$ GeV and $m_{H^\pm} = 150$ GeV, assuming $M_{\tilde{Q}} > M_{\tilde{D}}$.

and production cross sections) measured at typical linear collider experiments with polarized beams. We have found that under favourable conditions the fundamental MSSM parameters except $A_{t,b}$ can be determined with errors of $1\,\%$ to $2\,\%$, assuming an integrated luminosity of $1\ \mathrm{ab}^{-1}$. The parameter A_t can be determined within an error of $2 - 3\,\%$ whereas the error of A_b is likely to be of the order of $50\,\%$. More details can be found in [4].

3. CP Asymmetries in Sfermion Decays

As the sfermions are scalar particles and they usually have two–body decay modes, it is not straightforward to construct a CP sensitive asymmetry involving their decays. In the case of top squarks one can use a three–body decay [17], for the other sfermions one has to consider cascade decays. In our paper [6] we have considered the decay chain

$$\tilde{f} \to f\tilde{\chi}_j^0 \to f\tilde{\chi}_1^0 \, Z \to f\tilde{\chi}_1^0 \, \ell \, \bar{\ell} \ \ (f\tilde{\chi}_1^0 \, q \, \bar{q}), \tag{3.1}$$

where $\ell = e, \mu, \tau$, and q denotes a quark. We have defined a T-odd correlation for the leptonic decay

$$O_{\mathrm{odd}}^\ell = \mathbf{p}_f \cdot (\mathbf{p}_\ell \times \mathbf{p}_{\bar{\ell}}), \tag{3.2}$$

and for the hadronic decays as

$$O_{\mathrm{odd}}^q = \mathbf{p}_f \cdot (\mathbf{p}_q \times \mathbf{p}_{\bar{q}}), \tag{3.3}$$

where $\mathbf{p}$ denotes the three-momentum of the corresponding fermion. We define the corresponding T-odd asymmetries as

$$\mathcal{A}_{\mathrm{T}}^{\ell,q} = \frac{\Gamma(O_{\mathrm{odd}}^{\ell,q} > 0) - \Gamma(O_{\mathrm{odd}}^{\ell,q} < 0)}{\Gamma(O_{\mathrm{odd}}^{\ell,q} > 0) + \Gamma(O_{\mathrm{odd}}^{\ell,q} < 0)} \tag{3.4}$$

which by CPT are also CP asymmetries. This CP asymmetry is similar to that proposed in [24], however, we calculate the asymmetry in the full phase space of the decay chain. For the measurement of $\mathcal{A}_{\mathrm{T}}^{\ell}$ or $\mathcal{A}_{\mathrm{T}}^{q}$ it is necessary to be able to distinguish between the charges of ℓ^+ and ℓ^- or q and $\bar{q}$. In the case $\ell = e, \mu, \tau$ this should be possible experimentally on an event by event basis at an e^+e^- linear collider [3]. $\mathcal{A}_{\mathrm{T}}^{q}$ will be measureable in the case of $q = c, b$, where flavour reconstruction is possible [25].

As an example we have calculated $\mathcal{A}_{\mathrm{T}}^{\ell}$ for $\tilde{\tau}_1$ decay, considering the decay chain $\tilde{\tau}_1 \to \tau\, \tilde{\chi}_2^0$, $\tilde{\chi}_2^0 \to Z\, \tilde{\chi}_1^0$, $Z \to \ell\, \bar{\ell}$, for $\ell = e, \mu, \tau$. As input parameters we have chosen $m_{\tilde{\tau}_1} = 300$ GeV, $m_{\tilde{\tau}_2} = 800$ GeV, $\tan\beta = 10$, $|A_\tau| = 1000$ GeV, $\varphi_{A_\tau} = 0$, $m_A = 800$ GeV, $M_2 = 280$ GeV, using the GUT relation $|M_1| = 5/3 \tan^2\theta_W M_2$

In Fig. 4a we show the contour lines for the branching ratio $\mathrm{BR}(\tilde{\tau}_1 \to \tau\, \tilde{\chi}_1^0\, \ell\, \bar{\ell}) = \mathrm{BR}(\tilde{\tau}_1 \to \tau\, \tilde{\chi}_2^0) \times \mathrm{BR}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0) \times \mathrm{BR}(Z \to \ell\, \bar{\ell})$ in the φ_{M_1}-φ_μ plane for $M_2 = 280$ GeV and $|\mu| = 300$ GeV. For $\mathrm{BR}(\tilde{\tau}_1 \to \tau\, \tilde{\chi}_1^0\, \ell\, \bar{\ell})$ we always sum over $\ell = e, \mu, \tau$. We choose $M_{\tilde{E}} > M_{\tilde{L}}$ since in this case the $\tilde{\tau}_1$-τ-$\tilde{\chi}_2^0$ coupling $|a_{12}^{\tilde{\tau}}|$ is larger, which implies a larger branching ratio $\mathrm{BR}(\tilde{\tau}_1 \to \tau\, \tilde{\chi}_2^0)$ than for $M_{\tilde{E}} < M_{\tilde{L}}$. In a large region of the parameter space we have $\mathrm{BR}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0) = 1$, and we take $\mathrm{BR}(Z \to \ell\, \bar{\ell}) = 0.1$. In Fig. 4b we show the φ_{M_1} and φ_μ dependence of $\mathcal{A}_{\mathrm{T}}^{\ell}$. The value of $\mathcal{A}_{\mathrm{T}}^{\ell}$ depends stronger on φ_{M_1}, than on φ_μ. The sign of $\mathcal{A}_{\mathrm{T}}^{\ell}$ is essentially determined by the sign of φ_{M_1}.

The asymmetries $\mathcal{A}_{\mathrm{T}}^{b(c)}$ can be calculated from $\mathcal{A}_{\mathrm{T}}^{\ell}$ by replacing the leptonic Z coupling by the $Zq\bar{q}$ coupling. This gives

$$\mathcal{A}_{\mathrm{T}}^{b(c)} \approx 6.3(4.5) \times \mathcal{A}_{\mathrm{T}}^{\ell}. \tag{3.5}$$

Based on our results for the asymmetry $\mathcal{A}_{\mathrm{T}}^{\ell}$ in $\tilde{\tau}_1 \to \tau\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tau\ell^+\ell^-$ and the branching ratio we give a theoretical estimate of the number of produced $\tilde{\tau}_1$'s necessary to observe the T-odd asymmetry. As an example we take the point denoted by $\bullet$ in Fig. 4, with $\varphi_\mu = \pi/2$ and $\varphi_{M_1} = \pi/2$. For this point $\mathrm{BR} \approx 2.5 \times 10^{-2}$ and $|\mathcal{A}_{\mathrm{T}}^{\ell}| \approx 3 \times 10^{-2}$. For the decay $\tilde{\tau}_1 \to b\bar{b}\tilde{\chi}_1^0\tau$, on the other hand, $\mathrm{BR} \approx 3.6 \times 10^{-2}$ and $|\mathcal{A}_{\mathrm{T}}^{b}| \approx 1.9 \times 10^{-1}$. In this example the asymmeties $\mathcal{A}_{\mathrm{T}}^{\ell,q}$ should be measurable at an e^+e^- linear collider with $\sqrt{s} = 800$ GeV and an integrated luminosity of $500\ fb^{-1}$ for $m_{\tilde{\tau}_1} = 300$ GeV. It is clear that detailed Monte Carlo studies taking into account background and detector simulations are necessary to get a more precise prediction of the expected accuracy. For a Monte Carlo study on a T-odd observable in neutralino production and decay see [26].
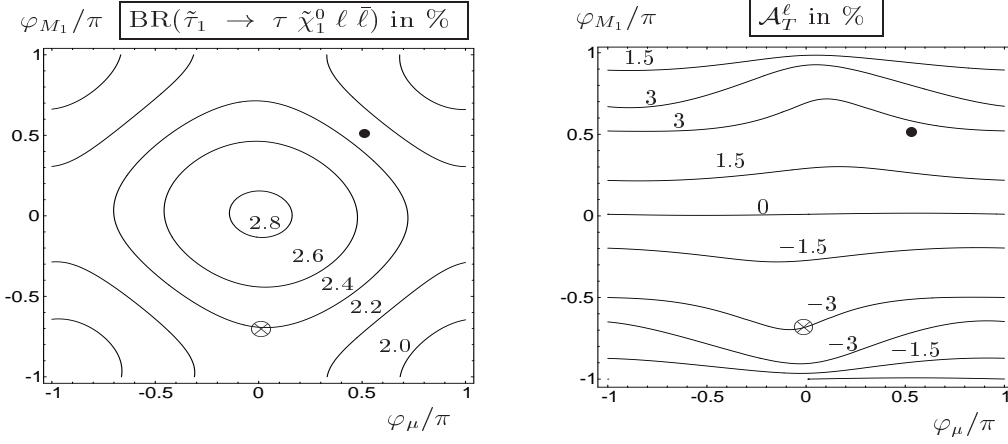
Acknowledgements

Figure 4: Contour lines of the branching ratio for $\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau \ell \bar{\ell}$ and asymmetry A_T^ℓ in the φ_{M_1}-φ_μ plane for $|\mu| = 300$ GeV and $M_2 = 280$ GeV, taking $\tan\beta = 10$, $A_\tau = 1000$ GeV, $m_{\tilde{\tau}_1} = 300$ GeV, $m_{\tilde{\tau}_2} = 800$ GeV for $M_{\tilde{E}} > M_{\tilde{L}}$. The point denoted by $\bullet$ is for the theoretical estimate of the necessary number of produced $\tilde{\tau}_1$'s (see text).

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